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Testing of the Sunstove Organization's Sunstove Solar Oven

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Testing of the Sunstove Organization's Sunstove Solar Oven

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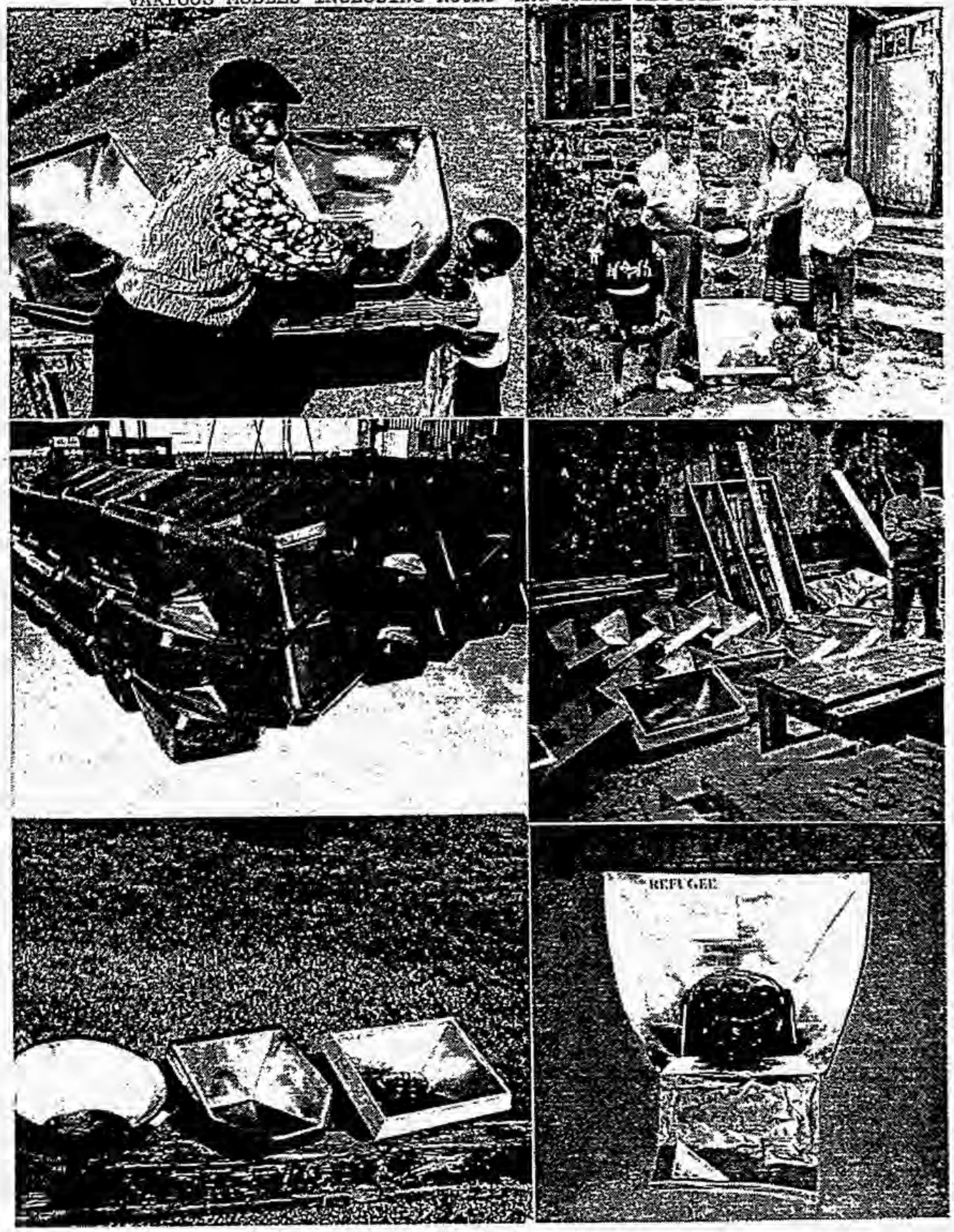
Abstract

A Sunstove Organization's Sunstove was tested at Sandia's Solar Thermal Test Facility. It was instrumented with five type K thermocouples to determine warm-up rates when empty and when a pot containing two liters of water was placed inside. It reached inside air temperatures above 115°C (240°F). It heated two liters of water from room temperature to 80°C (175°F) in about two hours. Observations were made on the cooling and reheating rates during a cloud passage. The adverse effects of wind on the operation of the solar oven were also noted.

SUNSTOVES ™ MOLDED--SOUTH AFRICA & RECTANGULAR--MEXICO
VARIOUS MODELS INCLUDING ROUND and PANEL REFUGEE™ UNIT



The Solar Thermal Design Assistance Center (STDAC) at Sandia National Laboratories evaluated a Sunstove from the Sunstove Organization, at Sandia's Solar Thermal Test Facility in Albuquerque NM. It was designed for single family household cooking. It is targeting developing countries' alternative energy markets where conventional fuels are not available and wood is the primary fuel used for cooking.

Because of the wide variety and types of solar cookers being manufactured it is very difficult to come up with a number, such as a figure of merit, to indicate how each will operate under various weather conditions. The best way to determine how a solar oven will operate is to test it under real life conditions[1,2]. These tests will not determine if a solar cooker is good or bad. It will, however, indicate the usefulness of the solar cooker for its intended usage.

The purpose of this test is to determine the basic operating characteristics of the Sunstove solar oven. For this report, only the basic tests of heat up rate, maximum temperature attained when empty, and the time to heat room temperature water to 80°C (175°F) were done. Further testing was too elaborate for the scope of this test. The solar oven is sized to cook about a two liter volume of food. Therefore, two liters was chosen as the volume of water to heat in the oven.

The Sunstove Organization's Sunstove solar cooker is a box type cooker. The difference between this cooker and other box type cookers is the reflectors are internal to the heated space rather than external (see fig. 2). Reflectors increase the solar collecting area, which enable the oven to obtain higher temperatures. The sides of the cooker are flared out to serve as internal reflectors and the bottom is blackened. It weighs about 8 lbs., has a molded polyethylene outer shell, fiberglass insulation, thin aluminum sheet interior (sides are reflective with the bottom blackened),and a 1.5 mm extruded acrylic sheet front that also serves as the door. The normal cooking temperatures of the oven allows the acrylic sheet to conform to the outline of the outer shell to create a seal. This solar oven sells for $20 to $25.

To measure the temperature inside the solar oven, five type K, 1/16" In600 sheathed, thermocouples were used. They were inserted through holes drilled into the side of the oven. This was done so the door, or window, seal would not be affected. Three of the thermocouples (front, middle, and back) measured the inside air temperature and two (side and middle) measured the water temperature. The front air thermocouple was centered on the front side and inserted one inch into the oven. The back air thermocouple was also centered on the back side inserted one inch into the inside of the oven. The middle air thermocouple was placed in the center of an imaginary line connecting the front and back air thermocouples. The thermocouples used to measure water temperature went through feedthroughs in the side of the pan. This preserved the seal between the lid and pot, which reduced the amount of water vapor escaping and, therefore, condensing on the front window. One measured the water temperature close to the side of the pot and the other measured the water temperature at the center. When the water was not present, these two thermocouples measured the air temperature on either side of the middle air thermocouple perpendicular to the imaginary line connecting the front and back thermocouples. The temperatures inside the solar oven, outside air temperature, wind speed, wind direction, and direct normal insulation (DNI) were measured and stored by a computer data acquisition system every thirty seconds.

Initial testing characterized heat up rate, the highest temperature reached, the temperature profile, and how long the solar cooker can remain in one position before it needs to be turned back into the sun. Figure 1 shows the normal heat up rate for the oven. The Sunstove will stabilize in temperature in about 25 minutes. The peak temperature was about 120°C (248°F). The oven needed to be repositioned approximately every hour to maintain optimum temperatures. For the remainder of the testing period the oven was repositioned every 30 minutes.

Later tests determined the ability of the solar oven to heat up water. Figure 2 is a picture of one of these tests in progress. A black ceramic coated covered pot filled with two liters of water was used. The oven was preheated for about one hour before the pot filled with water was placed inside. The water and pot were at room temperature before being placed in the oven. Figure 3 shows the results from this test. It heated water to 80°C (175°F) in less than two hours depending on wind conditions, which will be explained later. The maximum water temperature reached was 92°C (198°F).

The temperature distribution inside the Sunstove is shown in figure 4. There is a large difference between the front air thermocouple and the other thermocouples. Because of the shape of the Sunstove, the front air thermocouple is placed about one inch from the window and its seal, and about one inch from the bottom of the oven. This thermocouple is closest to any heat leaks and farthest from the heat source than any of the other thermocouples. The other thermocouples were much farther from the window, its seal, and the bottom of the oven.

During testing it was noticed the outside walls of the Sunstove were warm to the touch. For the test on 8/24 standard household fiberglass insulation, 3.5" thick, was wrapped around the outside of the Sunstove. As shown in figure 3, the extra insulation had little effect on the maximum temperature attained during preheat and on heating the water. From this it can be concluded most of the heat loss is from the large front window, or door. Adding more insulation to the sides would only marginally increase the inside temperature.

Wind always has an adverse effect on the performance of solar ovens. Figure 4 shows the inside air temperatures are depressed during high winds and increase during lower wind periods. The Sunstove never tipped over from the wind. A solar cooker with external reflectors is more prone to tipping over with high winds. The higher winds, however, would open the cover and let the hot air out. With the lowered inside air temperature it took longer to heat the water to 80°C (175°F) (see data on5/31 in figure 3). To prevent the cover from opening during high winds it was taped down. Use of the tape may seem extreme, but under normal circumstances the cook would employ some means to hold the acrylic sheet down. What windspeed would start to lift the acrylic sheet was not noted since orientation between wind direction and oven is very important. Since the orientation of the oven tracks the sun throughout the day and very often the wind changes direction during the day, the orientation of the oven to the wind is always changing. It would be best to fix the door closed rather than determining what wind speed and orientation would be needed to lift the door.

Clouds also have an adverse effect on the performance of the solar oven. Figure 5 shows the effect of several cloud passages on the measured inside air temperatures. The figure shows the air temperatures inside the oven decrease rapidly during very cloudy periods but recover nicely when the sun returns. The water temperatures during this same period are shown in figure 3 for the Sunstove. These data show that during minor cloudy periods the water temperature is only slightly affected. This is to be expected, since water has a much greater heat capacity than air.

These tests show the Sunstove can obtain sufficient temperatures to slow cook about a two liter quantity of food. It can heat water above 80°C (175°F) in a reasonable period of time, usually less than two hours. This temperature is important because 80°C (175°F) and higher is required to sterilize water and its contents, such as food. The Sunstove is stable in high winds but the wind can lift up the cover. This problem is easily overcome and should not detract from the usefulness of the oven. The Sunstove, at 20-$25, is more affordable than most solar ovens being manufactured for low income families in developing countries.

References

[1]S.C. Mullick, T.C. Kandpal and A.K. Saxena, *Thermal Test Procedure for Box-Type Solar Cookers*, Solar Energy, Vol. 39, No.4, pp353-360, 1987

[2]European Committee for Solar Cooking Research (ECSCR), Solar Cooker Test Procedure, Version 2, November 1993

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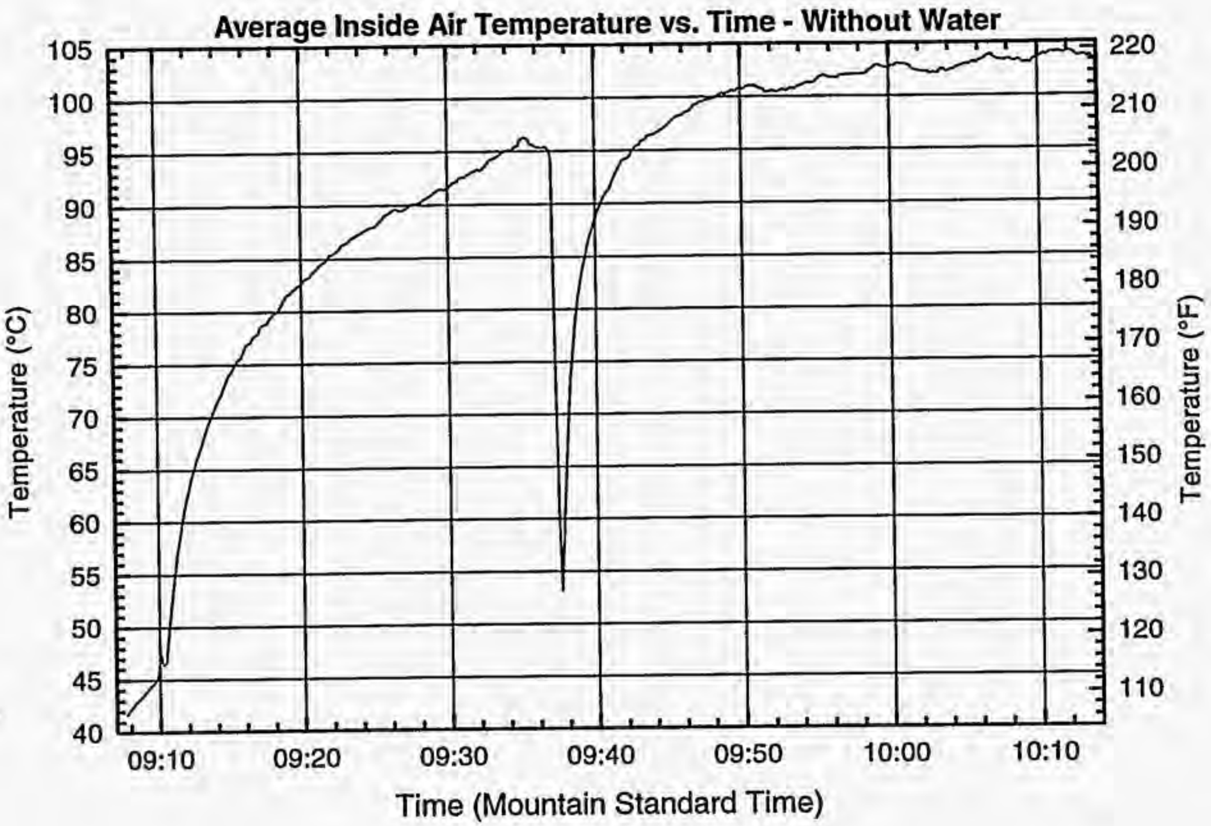

Figure 1: Ave. air temperature vs. time showing heat-up rates without water. The average of all five thermocouples is shown. Note the break at 9:37. The window, or door, was opened to observe how fast the oven recovers when opened during cooking.

Figure 2: Photograph of the Sunstove heating two liters of water in a pan. This also shows the extra insulation that was added in an attempt to reduce heat losses.

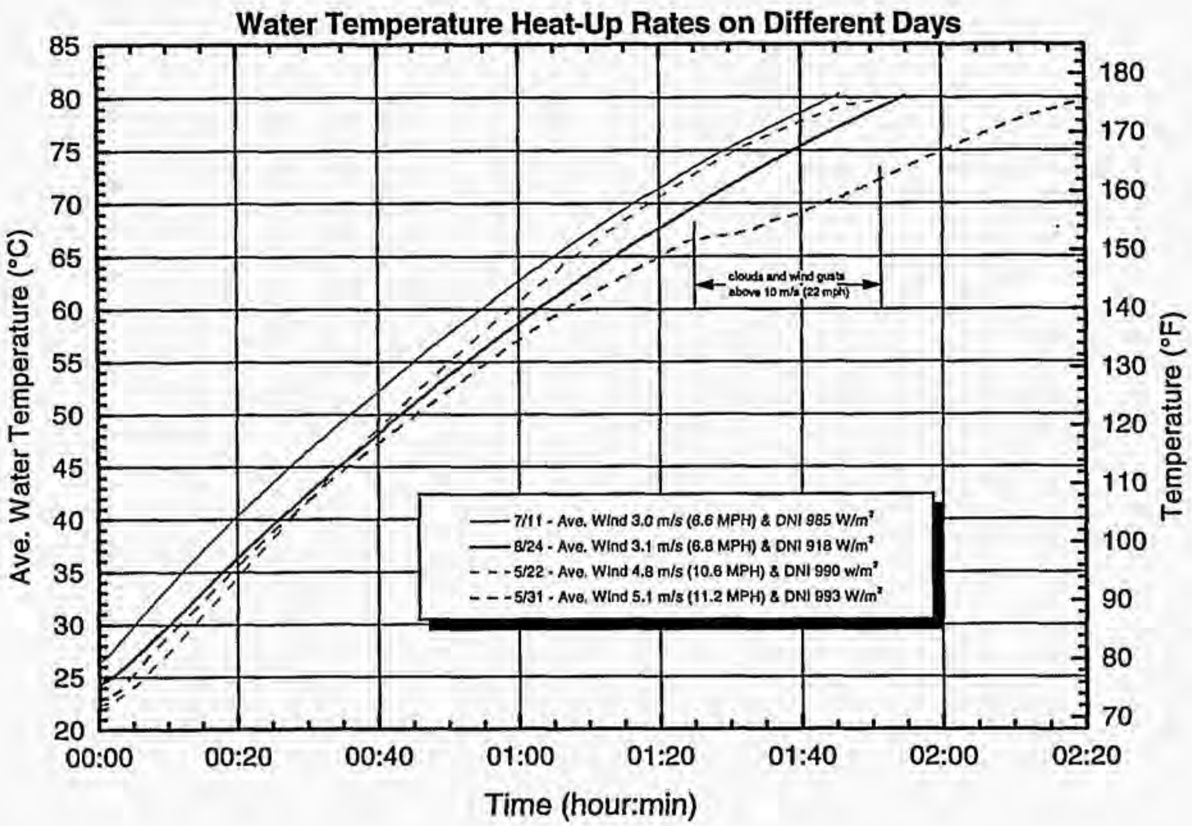

Figure 3: Ave. water temperature vs. time heating two liters of water. Notice the effects of wind on the temperature on 5/31.

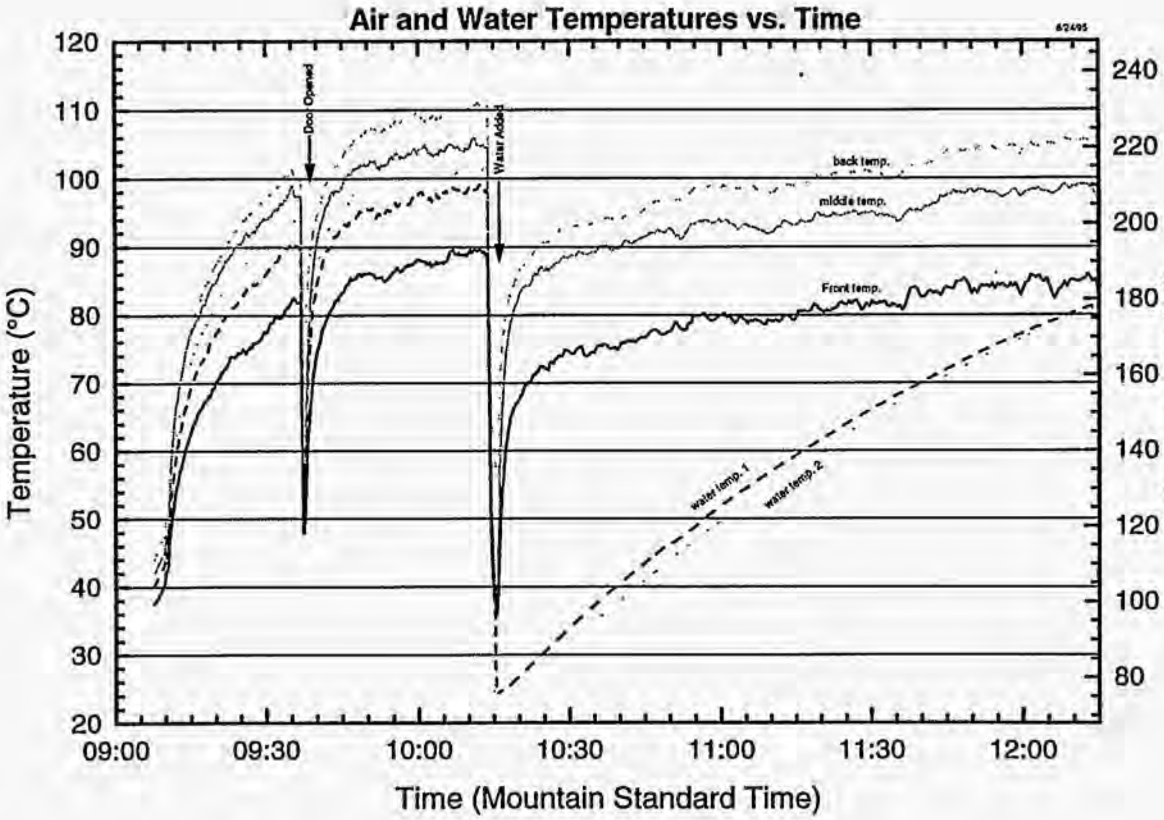

Figure 4: Air and water temperature distribution inside the oven during a typical test.

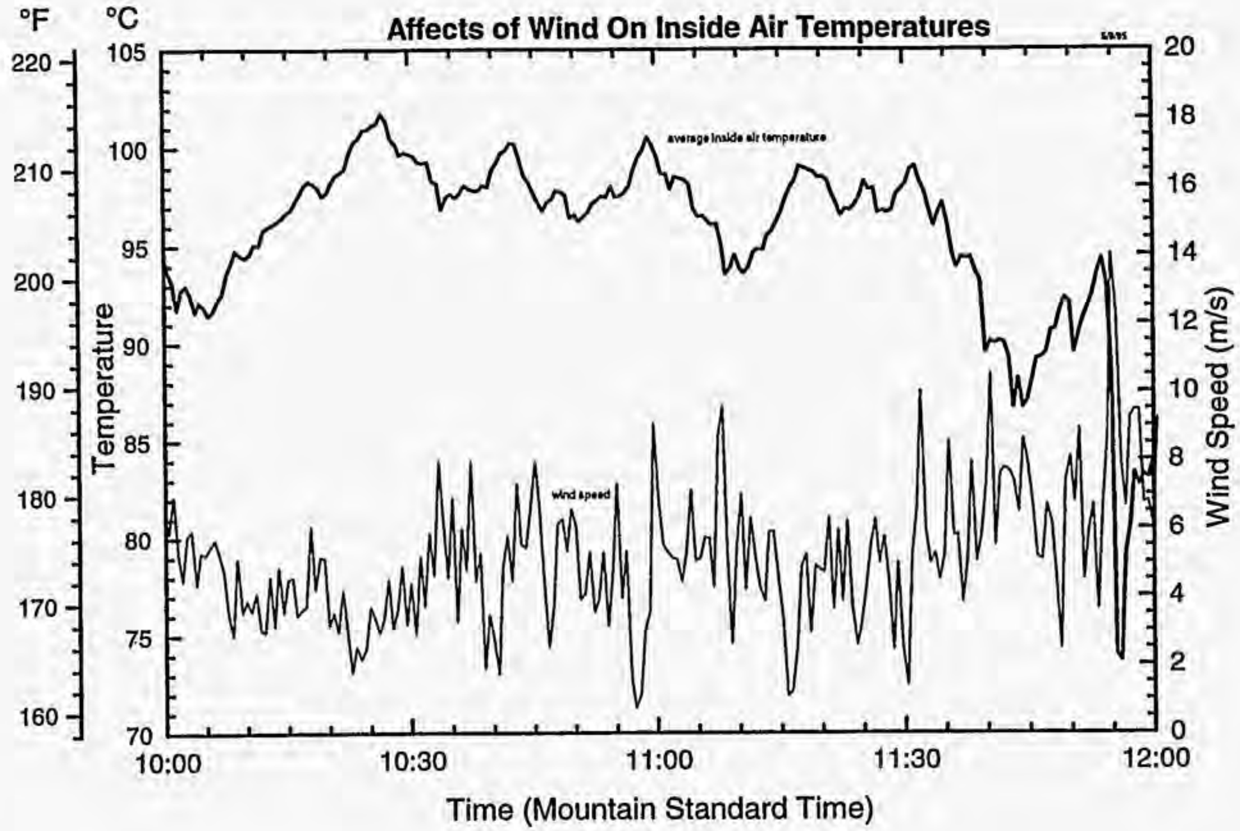

Figure 5: Temperature and wind speed vs. time. This shows the effect of wind on the inside temperatures of the solar oven.

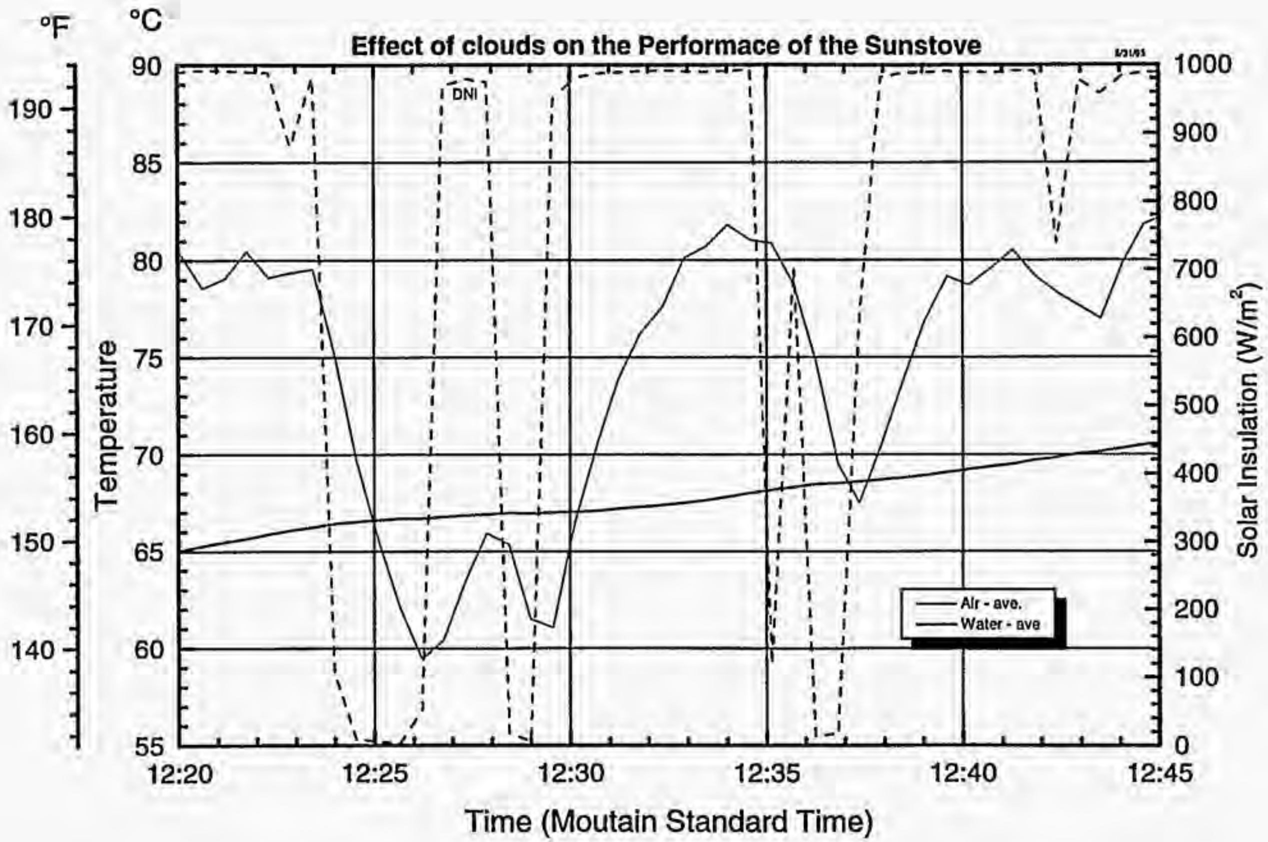

Figure 6: Average air temperature and Direct Normal Insulation (DNI) vs. time showing the effect of clouds on the performance of the solar oven.

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